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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

**INVESTIGATION OF THE IMPACT OF NATURAL AND
ANTHROPOGENIC FACTORS ON THE KURA-ARAZ
LOWLAND AND SURROUNDING TERRITORIES BASED
ON AEROSPACE METHODS**

Specialty: 5409.01 - Geomorphology

Field of science: Geography

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The research work was carried out at the "Geomorphology and natural risks" department of the Institute of Geography named after academician H.A.Aliyev of the Azerbaijan National Academy of Sciences.

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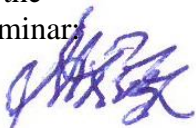
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GENERAL CHARACTERISTICS OF THE WORK

The actuality and the investigation level of the topic. The relief formed as a result of the interaction of endogenous and exogenous processes as a basic element, which has characteristic static, morphological, lithological-structural, morphometric and geodynamic features, determines the differentiation, direction of development and stability of the human ecosystem. From this viewpoint, the environment-forming function of relief and its impact on the environment have become the subject of research in the recently developed direction of ecological geomorphology. The consequences of global climate change, especially the development of desertification and the increasing human impact on the environment, the increase in geomorphological risks and natural disasters, require a geomorphological approach to changes in ecosystems and ecogeomorphological assessment of the natural environment. In modern times, the application of Geographic Information Systems (GIS) and aerospace methods allows us to obtain important results in the detailed study of relief-forming processes and the impact of anthropogenic activities on the geomorphosystem in terms of qualitative and quantitative indicators. It is the use of GIS technology, which can systematically collect, automatically calculate, process and describe multitemporal spatial data in a short time, significantly increases the objectivity, accuracy and efficiency of research in the field of ecogeomorphological assessment and forecasting.

The Kur-Araz lowland and surrounding areas, which is considered an important agricultural region and covers 30.25% of the country's territory and is inhabited by up to 20% of the population, and some international and regional transport corridors, communication lines and the Kur-Baku drinking water pipeline pass through the territory. For this reason, there is a need to conduct detailed ecogeomorphological studies. The development of various types of endogenous (mud volcanism, modern tectonic movements, seismicity) and exogenous (fluvial, arid-denudation, thalassogenic,

swamping, eolian and salinization) processes, including anthropogenic factors (irrigation erosion, intensive grazing, oilfield exploitation, production of building materials, etc.) create more complex ecogeomorphological conditions in the study area and increase the urgency of solving the problems thought in the dissertation.

In the field of ecological geomorphology, foreign scientists D.R.Coats, D.A.Timofeyev, Y.G.Simonov, M.Panizza, V.I.Krujalin, and others, and in Azerbaijan N.Sh.Shirinov, Kh.K.Tanriverdiyev, H.A.Khalilov, A.S.Safarov, R.Y.Guliyev, E.K.Alizade, V.A.Guluzade, R.S.Abdullayev, S.A.Tarikhazar, T.R.Gurbanov, M.M.Mehbaliyev and others conducted research and obtained relevant results.

Object and subject of research. The object of research is the Kur-Araz lowland and surrounding areas, and the subject is the role of natural and anthropogenic factors in the formation of ecogeomorphological conditions and assessment of the study area.

Purpose and objectives of the research. The main purpose of the dissertation is to study the impact of natural and anthropogenic factors on the ecogeomorphological conditions of the Kur-Araz lowland and surrounding areas. For this purpose, the following tasks were set and fulfilled in the dissertation:

- analysis of research conducted in this field in Azerbaijan and abroad on the basis of collected literature sources;
- creation of a geo-database of natural and anthropogenic factors affecting the ecogeomorphological conditions of the area on the basis of the analysis of the collected literature, fund materials, cartographic sources and satellite images;
- analysis of the role of endo and exodynamic processes, static, hydrogeological and anthropogenic factors in the formation of ecogeomorphological conditions of the area;
- analysis of the dynamics of natural and anthropogenic factors affecting the ecogeomorphological conditions of the area;
- ecogeomorphological assessment and zoning of the terrain on the basis of individual and complex factors.

Research methods. Morphometric, cartographic, mathematical-statistical, multicriterial analysis (analytical hierarchical process), ecogeomorphological zoning, digital modeling in the GIS environment, spatial, geostatistical, three-dimensional, geometric analysis, supervised, unsupervised classification methods and comparative analysis of satellite images were used in the dissertation work.

The main provisions of the defense:

1. Analysis of natural and anthropogenic factors affecting the ecogeomorphological conditions of the area;
2. The importance of specific weights of individual factors (endogenous, exogenous, morphometric and anthropogenic) in the assessment of ecogeomorphological conditions of the territory;
3. Ecogeomorphological assessment and zoning of the area considering the specific weights and effects of individual factors.

Scientific novelty of the research:

- The interaction and dynamics of natural and anthropogenic factors affecting the ecogeomorphological conditions of the area was analyzed;
- Gradations assessing the impact of natural and anthropogenic factors on the ecogeomorphological conditions of the area were identified;
- Specific weights of individual factors affecting the ecogeomorphological conditions of the area were determined;
- Distribution features of areas with different ecogeomorphological tensions were determined, ecogeomorphological assessment and zoning of the area was carried out considering the specific weights of individual factors.

Theoretical and practical significance of the research. The theoretical and practical significance of the results of the study is in the development of methods for ecogeomorphological assessment and zoning of plain areas using GIS technology. The dissertation can also be used for the effective placement and design of economy and infrastructure, the implementation of environmental measures, as

well as future scientific research works on the ecogeomorphological conditions of the area.

Approbation and application of the research. The main results and provisions of the dissertation work were presented at the scientific seminar of the Institute of Geography named after academician H.A.Aliyev of the Azerbaijan National Academy of Sciences. and at the following scientific-practical conferences of national and international importance: Republican conference on "Heydar Aliyev and the development of geography in Azerbaijan" (Baku, 2013), Republican conference on "Development of geography in the years of independence" (Baku, 2013), Republican conference on "Directions of the application of modern geography" (Baku, 2014), Republican conference on "Geographical problems of Azerbaijani regions" (Baku, 2016), "Global economic conditions, and economic-geographical position of Azerbaijan" (Baku, 2017), II International Scientific Conference of Young Scientists and Researchers on "Multidisciplinary approaches in solving modern problems of fundamental and applied sciences" (Baku, 2020), XXV International Scientific Symposium on "Civilizational bridges between nations and cultures" (Kiev, 2022).

Sixteen scientific articles and theses were published in the dissertation.

The name of the institution where the dissertation work was carried out: Dissertation work was implemented in the department of "Geomorphology and natural risks" at the Institute of Geography named after academician H.A.Aliyev of the Azerbaijan National Academy of Sciences.

The structure of the dissertation. The dissertation, with a volume of 167 pages, consists of 4 chapters, introduction (4 pages), results and recommendations (2 pages), and a list of references of 169 titles (22 pages), appendices (12 pages). I Chapter – 20 pages, II Chapter – 41 pages, III Chapter – 35 pages, IV Chapter – 31 pages. The dissertation consists of 196231 characters, without tables, graphs, a list of references and appendices.

MAIN CONTENT OF THE RESEARCH

In the **introduction**, the relevance of the topic is substantiated, the purpose and objectives of the research are defined, the object and subject, scientific novelty and provisions, and practical significance are noted.

The first chapter of the dissertation is devoted to "**Problem statement, current state of study, the object of research and methodological bases.**" The study of environmental problems associated with increased anthropogenic impact on the environment, since the second half of the twentieth century, has led to the emergence of an ecological direction in geomorphology - ecological geomorphology, as well as in other fields of science. As an independent field of science, its basic theoretical concepts and notions, terms (functions of environment formation, geomorphological risks, threats and the geodynamic processes that cause them), methodological principles have been identified..

The relief created by interacting the lithosphere, atmosphere and hydrosphere plays an important role in the formation of ecological conditions in the geographical area, influencing other natural components, such as the contact surface, being an indicator and information carrier of the processes occurring in geographical layer. Relief is also a key factor that determines human life and economic activity, determines the regularity of the distribution of natural resources in the area, has recreational and aesthetic potential. From this perspective, the relief causes the formation of one or another characteristic ecogeomorphological environment by influencing climatic indicators (temperature, atmospheric pressure, humidity, etc.), the distribution of surface and groundwater, organic and inorganic minerals, energy, etc., differentiation of their quantitative and qualitative indicators, as well as the distribution of soil and vegetation, fauna, etc. Here the morphostructure and morphosculpture of the relief, geodynamics and stability, lithological-geochemical composition, morphogenetic features, anthropogenic deformation, morphometric, etc. indicators play an important role. From this viewpoint, in the discipline of ecological

geomorphology, the emphasis on the environment-forming function of relief as a fundamental element of the ecosystem is of great scientific and theoretical importance.¹

It is observed gradual desertification of the study area from west to east (increase in absolute maximum temperature to 43°C, decrease in humidity to 0.2–0.3, etc.), the poverty of surface water (flow rate of 0.5-1 l/sec/sq. km), increasing salinity, morphometric quantitative indicators, geodynamic stress (gravity, tectonic uplift, seismicity, mud volcanism in the eastern part, arid-denudation processes, etc.) as well as increases from depressions and lowlands to low range and blocs. Also the lithological composition of sediments and rocks, the depth and salinity of groundwater, anthropogenic deformation of the relief (irrigation erosion, production of building materials, etc.) have significantly complicated the ecological and geomorphological conditions in the area. Thus, in addition to the above, the Kur-Araz lowland and surrounding areas, where most of Azerbaijan's agriculture is located and where international transport corridors pass, and the sensitivity of the surrounding areas to natural and anthropogenic impacts increase the relevance of ecogeomorphological research.

Although some work has been done in the field of ecological-geomorphological study of Azerbaijan as a whole and its individual territories dynamics of geodynamic (endogenous and exogenous), morphometric (horizontal and vertical fragmentation, hypsometry and slope) and anthropogenic (artificial fragmentation) factors, specific weights and complex effects on the ecological and geomorphological conditions of the area were excluded from the study. The implementation of all this in the GIS environment and with the application of aerospace methods shows that it is of great scientific and practical importance, along with the novelty of the research.

¹ Khalilov, H.A. Environmental formation function of relief in the Talysh mountain system (ecogeomorphological aspect of research) // - Baku: Proceedings of Azerbaijan National Academy of Sciences, The Sciences of Earth, - 2010. No 2, - p. 24-27.

According to the scheme of geomorphological zoning of the territory of the Republic of Azerbaijan the object of research covers Kura-Araz lowland subregion including the geomorphological zones of Shirvan, South-Eastern Shirvan, Salyan, Kuryany, Mugan, Ajinohur-Jeyranchol subregion included the geomorphological zones of Ajinohur, Langabiz-Alat, Harami, Caucasus, Lesser Caucasus sloping plain subregion included the geomorphological zones of Garabakh and Mil. These subregions are included in the geomorphological region of the Kura intermountain depression². According to the scheme of geomorphological zoning of the Caspian Sea coast, the study area covers the Shirvan, Kura delta and Gizilagaj zones of the Kura geomorphological coastal subregion³. The total area of the study territory is 26201 sq. km.

The second chapter of the dissertation is devoted to **"Geodynamic factors affecting the ecogeomorphological conditions of the Kur-Araz lowland and surrounding areas."** This chapter provides a detailed analysis of new and modern tectonic movements, seismicity, buried high, mud volcanism, fluvial, arid-denudation, swamping and thalassogenic processes.

Endogenous factors. Modern tectonic movements, which are the inherited continuation of new tectonic movements, seismic processes, mud volcanism in the north-eastern part, buried high and tectonic faults in the study area, are interrelated. Also, these endogenous factors determine the development of exodynamic processes in the area. For example, mud volcanoes, located on the longitudinal and transverse tectonic faults, characterized by high seismicity and generally endodynamic activity, intensive manifestations of modern tectonic movements, and their eruption products (easy-to-wash breccias, brackish waters, etc.) in the Lower

² Alizade, E.K. Geomorphological zoning, Geography of the Republic of Azerbaijan, Physical geography: [in 3 volumes] / E.K.Alizade, Kh.K. Tanriverdiyev, H.A.Khalilov [and others]. - Baku: Europe, - v. 1. - 2014. - p. 130-131.

³ Shirinov, N.Sh. Nature and ecology of the Caspian Sea and its shores / N.Sh.Shirinov, Kh.A.Valiyev, Y.G.Aliyev. - Baku: Elm, - 1998. - p. 136.

Kura depression, accelerate the development of harmful exogenous processes such as line and field erosion, salinization and clay karst. In assessing the geomorphological risk of the area, the impact of endogenous factors, recurrence and proximity to them is important. Based on this consideration, the probable seismicity of the settlements located in the study area and the degree of risk due to the proximity to mud volcanoes were calculated on the basis of the analysis of relevant maps. It has been determined by us that 609 settlements with a population of more than 1230000 people have a medium, 382 settlements with a population of more than 750000 have a high probability of seismicity. 18 settlements with a population of more than 170000 people have a medium and high risk due to the proximity to mud volcanoes.

According to our analysis, it was found that 24 of the 45 buried high⁴ located in the study area corresponded to anticline structures created relief forms with relatively clear, mostly symmetrical positive morphological configurations, and 21 to monoclinic formed structures created slope relief forms. Buried high (Kursangi, Padar, Sorsor, Shaparti, etc.) manifested in the form of positive relief forms under the influence of intensive shielding tectonic movements caused mainly by linear and surface erosion, deflation, and clay karst. Weakly manifested buried high (Shahsunun, Okhchugobu, Agchala, Khankishi, etc.) complicated the ecogeomorphological conditions of the area, creating favourable conditions for developing eolian, salinization, swamping processes, meanders and former river-beds.

Exogenous factors. Exogenous processes, characterized by great destructive (creative) and creative (constructive) activity, play an important role in the formation of ecogeomorphological conditions in interaction with endogenous, static and anthropogenic factors, other components of the physical and geographical conditions of the area. Flooding, lateral erosion of rivers (areas along the Kura and Araz rivers), ravine-gorge erosion, surface washing, clay karst (southern blocs of Acinohur foothills, Langabiz-Alat, Harami districts, Duzdag

⁴ Shirinov, N.Sh. The latest tectonics and relief development of the Kura-Araks depression / N.Sh.Shirinov. - Baku: Elm, - 1975. - P. 170.

and Bozdag blocs), deflation, eolian accumulation, salinization (in certain parts of the Southeastern Shirvan, Mil, Mugan and Salyan plains), coastal washing processes (Pirsaat, Bandovan Cape, Gizilagaj Bay, etc.) observed in the study area are considered as exodynamic processes creating geomorphological risks and threats. Constructive relief-forming processes such as alluvial, alluvial-proluvial, alluvial-delta, alluvial-lake-delta, alluvial, proluvial-deluvial, alluvial-marine sedimentation of accumulative origin developed here have created relatively favorable ecogeomorphological conditions. According to the analysis of vegetation (NDVI), humidity (NDMI), erosion (NBaI), salinization (NDSI) indices, obtained by processing of “Landsat” satellite images for 1976, 1987, 2002, and 2017⁵, and land cover and land-use maps (LULC) obtained from the classification of the mentioned satellite images, it was determined that an increase in the areas of anthropogenic impact and a decrease in the area of distribution of natural exodynamic processes.

Although the natural swamping process in the Kur-Araz lowland (Sarisu lake-swamp system) and on the shores of Gizilagaj Bay accompanied by intensive salinization during the hot season has some harmful effects on the life and economic activity of the population, it enriches the diversity of hydromorphic landscapes and wildlife, plays a role in the protection of ecological balance. For example, the drying of the Garasu swamp in the southeast of the Shirvan Plain in 1960–70 to expand arable land resulted in the extinction of fauna and flora in the area and the drying up part of Lake Hajigabul, which is the main source of nutrition⁶.

The study analyzes the dynamics of abrasion (washing), flooding and accumulation processes over a period of 43 years due to fluctuations in sea level in the Kura geomorphological coastal subregion of the Caspian coastal zone on the basis of processing and comparing Landsat multispectral satellite images for 1976, 1996, and

⁵ <https://earthexplorer.usgs.gov>

⁶ Shirinov, N.Sh. Geomorphological structure of the Kura-Araz depression (Morphosculptures) / N.Sh.Shirinov. - Baku: Elm, - 1973. - P. 44.

2019. According to our calculations, 402,854 sq. km of coastal area was flooded during 1976–96 due to the 2.43 m rise in the level of the Caspian Sea, and the area of accumulation processes was 5.39 sq. km. Because of abrasion and flooding processes in the coastal areas, Sarigamysh, Dalgali, Sahiloba, Mayak-1, Mayak-2, Subh villages of Neftchala region, Liman city, Shirvanli, Kurdili, Narimanabad-2, Balikchilar, Uzumchuluk, Narimanabad-1 villages of Lankaran region, as well as the transport network and arable lands were also severely damaged. In the following period (1996–2019), mainly due to the stabilization and decrease in the Caspian Sea level (1.39 m), the coastline advanced to the sea and advanced accumulation processes increased coastal areas by 305,678 sq. km compared to the previous period. The coastal area subjected to washing and flooding during the period was 22,562 sq. km. The lowering of the sea level has a significant impact on the development of accumulative processes on the coast, salinity, swamps (Gizilagaj Bay, etc.), the erosion base of the Kura River, causing some damage to the port economy.

The third chapter of the dissertation analyzes **"Static, hydrogeological and anthropogenic factors affecting the ecogeomorphological conditions of the Kura-Araz lowland and surrounding areas."**

Lithological factors. Oligocene-Holocene aged lithological factors are composed of sandy-clay sediments, sandstones, pebbles, marls, conglomerates, tuffs, breccias in the Kura-Araz lowland and surrounding areas. Along with the structure of morphostructures, lithological factors, with denudation resistance or washing resistance, chemical composition and water permeability, determine the intensity of fluvial, arid-denudation, salinization and swamping processes in the study area. For example, the predominance of sandy-clayey rocks and mud volcanic breccias in the anticline and ridges in the north-eastern part of the area results in the development of ravine-erosion, clay karst, and thus bedland-type areas. New Caspian age sediments, in some cases came to the surface, which are unresistant to denudation, with fragility and a high degree of mineralization, create

favorable conditions for developing eolian and salinization processes in the South-Eastern Shirvan plain.

Hydrogeological factors. The regime of groundwater in the Kur-Araz lowland and in different parts of the surrounding areas depends on natural and anthropogenic factors. The depth of groundwater and the degree of mineralization of groundwater fed mainly by filtration of water filtered from rivers and irrigation systems have a significant impact on the development of salinization and swamping processes in the area. According to our calculations, in 22.81% of the study area (Shirvan, South-Eastern Shirvan, Salyan, Mugan, Kurboyu and certain parts of the Garabagh plains) the depth of groundwater is up to 2 m, and the degree of mineralization is 10–50 g / l is greater than and above.

Morphometric indicators. Morphometric indicators such as horizontal and vertical fragmentation, hypsometry, slope, average slope and aspect, quantitatively reflect the development patterns of relief, the manifestations of endogenous and exogenous processes. The mentioned morphometric indicators were analyzed and for ecogeomorphological assessment, gradations of morphometric indicators were separated and area indicators were calculated in the Kur-Araz lowland and surrounding territories. Among the morphometric indicators (hypsometry, vertical fragmentation, slope and aspect), it was determined that artificially increased horizontal fragmentation is the main indicator creating ecogeomorphological tension in the area. According to our calculations, the absolute value of general (natural and anthropogenic) horizontal fragmentation is 0–7.24 km/sq. km, the absolute value of natural horizontal fragmentation caused by linear erosion is 0–2.92 km/sq. km, the value of vertical fragmentation is 0–532 m, the value of absolute height varies between -27–0 and 0–923 m, the value of the actual slope varies between 0–59.97 °, and the value of the mean slope varies between 0–0.3 °. Due to the smooth relief of the area, the aspect of the slopes is observed mainly in the foothills and uplands. The calculated aspects were conventionally divided into four degrees according to the intensity of the erosion processes and their areas

were calculated: weak (smooth areas; 5259.37 sq. km, 20.07%), moderate (western, north-western, northern, north-eastern slopes; 10155,26 sq. km, 38.75%), medium (eastern, southeastern, southwestern slopes; 8129.43 sq. km, 31.03%) and high (southern slopes; 2656.79 sq. km, 10.14%) tension aspects.

The correlation coefficient calculated by us between natural horizontal fragmentation and hypsometry is 0.58, between natural horizontal fragmentation and vertical fragmentation is 0.63, and between natural horizontal fragmentation and mean slope was 0.65. This shows that the relationship between these indicators is moderate. The correlation coefficient between the mean slope and hypsometry is 0.71, between the vertical fragmentation and hypsometry is 0.74, and between the mean slope and the vertical fragmentation is 0.81. This shows that, the relationship between the mentioned indicators is high. This correlation is confirmed by the regularity of the gradual increase in the natural-horizontal fragmentation (except for valleys in the plains), the slope and the average slope from the plains to the foothills and uplands, as well as the indicators of hypsometric and vertical fragmentation of relief in the Kur-Araz lowlands and surrounding areas. This is also clearly described in the relevant maps.

Anthropogenic factors. Direct and indirect anthropogenic impacts have gradually begun playing an important role in the formation of ecological and geomorphological conditions of the area, leading to the development of geodynamic processes in positive and negative directions. The implementation of such measures as, establishment of reserves (Gizilagaj, Turyanchay, Shirvan, Korchay), sanctuaries (Bandovan, Barda, Kichik Gizilagaj), national parks (Aggol, Shirvan) to maintain ecological balance, definition of flood protection zones, land recultivation (in the territory of Neftchala Iodine-bromine plant), cleaning of irrigation canals and collector-drainage systems from silt, concreting of the bottom (Khan gizi canal, etc.), application of drip irrigation in agro-parks, etc. serves to improve the ecological and geomorphological conditions of the area. Anthropogenic factors such as oil production (in Kursangi, Mishovdagh, Kalameddin, Neftchala, Durovdagh-Babazanan oil

fields), intensive grazing of large and small horned animals in pastures, production of construction materials (around Mingachevir city, Udullu and Atbulag villages of Hajigabul region, Bahramtapa settlement of Imishli region), artificial hydrological regime changes (reservoir activity), irrigation erosion and accumulation (artificial irrigation), accelerated the development of the amount of harmful hydrogeological (rising groundwater levels) and exodynamic (surface pollution, erosion, eolian, salinization, swamping) processes in the area.

The production process in the construction materials factories and sand-gravel quarries has led to the pollution of the surrounding areas with sedimentary materials, the formation of deflation, erosion sites, terricones, changes in fluvial processes in river valleys. For example, after the Bahramtapa hydrojunction, the Araz River bed was significantly altered due to sand and gravel production in the area, numerous ponds were formed, and the structure of the river valley and the flow of the river were almost disrupted.

In the cold half of the year, intensive grazing of large and small horned animals in areas used as winter pastures (South-Eastern Shirvan, Mugan, Mil plains, etc.) resulted in degradation of natural soil and vegetation, which in turn leads to surface erosion in heavy rainy weather in weak inclined areas, and in windy weather created favorable conditions for accelerating eolian processes. Intensively developed eolian processes in areas deprived of vegetation also cause significant damage to neighboring crops.

The exploitation of Mingachevir, Varvara, Mil-Mugan and Bahramtapa reservoirs had a significant impact on the hydrological regime of the Kura and Araz rivers and, indirectly, on changes in the ecological conditions of the area. The Upper Shirvan, Upper Garabagh, Bash Mil, Bash Mugan, Azizbeyov and other main canals, which took water from the mentioned reservoirs and were buried in the ground, expired. Because of intensive filtration of water from the main and numerous inter-farm and on-farm irrigation canals, and due to flooding in most small arable lands, the level of groundwater in thousands of hectares increases during the irrigation season. Rising

groundwater levels with high mineralization have resulted in the development of exogenous processes in the area, such as re-salinization and swamping, and loss of soil fertility in general. Soil drainage and collector systems (Bash Shirvan, Mil-Garabagh, Bash Mil-Mugan) created to prevent the above-mentioned harmful processes are also silt up after a certain time, the surface is covered with vegetation, water transport capacity is lost and saline water flows from them to the surrounding areas. The mentioned situations has further aggravated the ecogeomorphological conditions in the study area.

The dynamics of anthropogenic impact on the ecogeomorphological conditions of the area was analyzed and the degree was determined. According to our calculations based on the classification of satellite images, between 1976 and 2017, the sown areas where irrigation erosion and accumulation developed increased by 2456.72 sq. km (245672.28 ha). The average annual growth of sown areas in the mentioned period was 59.92 sq. km (5992.0 ha). According to another calculation made by us, the value of anthropogenic fragmentation in the study area varies between 0–7.23 km/sq.km. The western and south-eastern parts of the Shirvan plain, the western and southern parts of the South-Eastern Shirvan plain, the Salyan plain, the northern and central parts of the Mugan plain and the Garabakh plain are disintegrated by a dense irrigation network (more than 3 km/sq. km).

The fourth chapter of the dissertation is dedicated to **"Ecogeomorphological assessment and zoning of the Kur-Araz lowland and surrounding areas."** Ecogeomorphological assessment and zoning of the study area was carried out on the basis of qualitative and quantitative indicators of individual and complex relief forming factors, using GIS technology and remote sensing data, considering the specific weights of individual factors. Based on our assessment between 1 and 8 points, 4 ecogeomorphological zones were identified: weak, moderate, medium and high tension zones.

Estimation and zoning of ecogeomorphological tension of the study area due to **endogenous factors** was carried out on the basis of

proximity to mud volcanoes and regional tectonic faults, probable seismicity, quantitative indicators of modern tectonic movements (Table).

Weak tense (1–2 points) ecogeomorphological zones cover 69.29% of the total area (16320.614 sq.km). This region mainly includes the areas away from tectonic faults and mud volcanoes. The rate of tectonic subsidence in this zone, which is subject to intense tectonic bending and is characterized by low seismicity, is -5–0 mm / year. Moderate tense (3 points) zones, which make up 24.92% of the area (6528.212 sq. km), mainly cover areas closer to tectonic faults. The foothills of the region are subject to weak tectonic uplift (0–1 mm/year). The probable seismicity in areas of low and moderate tense is up to 7 on the Richter scale (Figure 1).

Medium (4–5 points) tense zones, located on tectonic faults and near mud volcanoes, and high (6–8 points) tense zones, covering the area of mud volcanoes in the Lower Kura depression, are distinguished by intensive tectonic uplift regime (above 1 mm/year) and high probability of seismicity (8–9 points). Medium and high tense zones make up 9.85% (2582.071 sq. km) and 2.94% (769.948 sq. km) of the Kur-Araz lowland and surrounding areas, respectively.

Ecogeomorphological assessment and zoning of the study area according to **exogenous factors** was performed out on the basis of supervised classification of multispectral satellite images. Considering into account the relationship of exogenous morphogenesis processes with morphostructures, the origin of relief forms, the impact on the ecogeomorphological conditions of the area, 24 subzones were divided within the four zones.

Weak (1–2 points; 11562.841 sq. km; 44.132%; 7 subzones) and moderate (3–4 points; 5832.136 sq. km; 22.259%; 6 subzones) tense zones include alluvial, alluvial-proluvial, proluvial-deluvial, deluvial, alluvial-lake-former river-bed, alluvial-delta, and alluvial- marine origin accumulative, denudation-accumulative and structural-denudation plains of Kur-Araz lowland, Navahi and Sabaduzu mountain depressions. Fluvial and weakly arid-denudation and swamping processes have developed in the area.

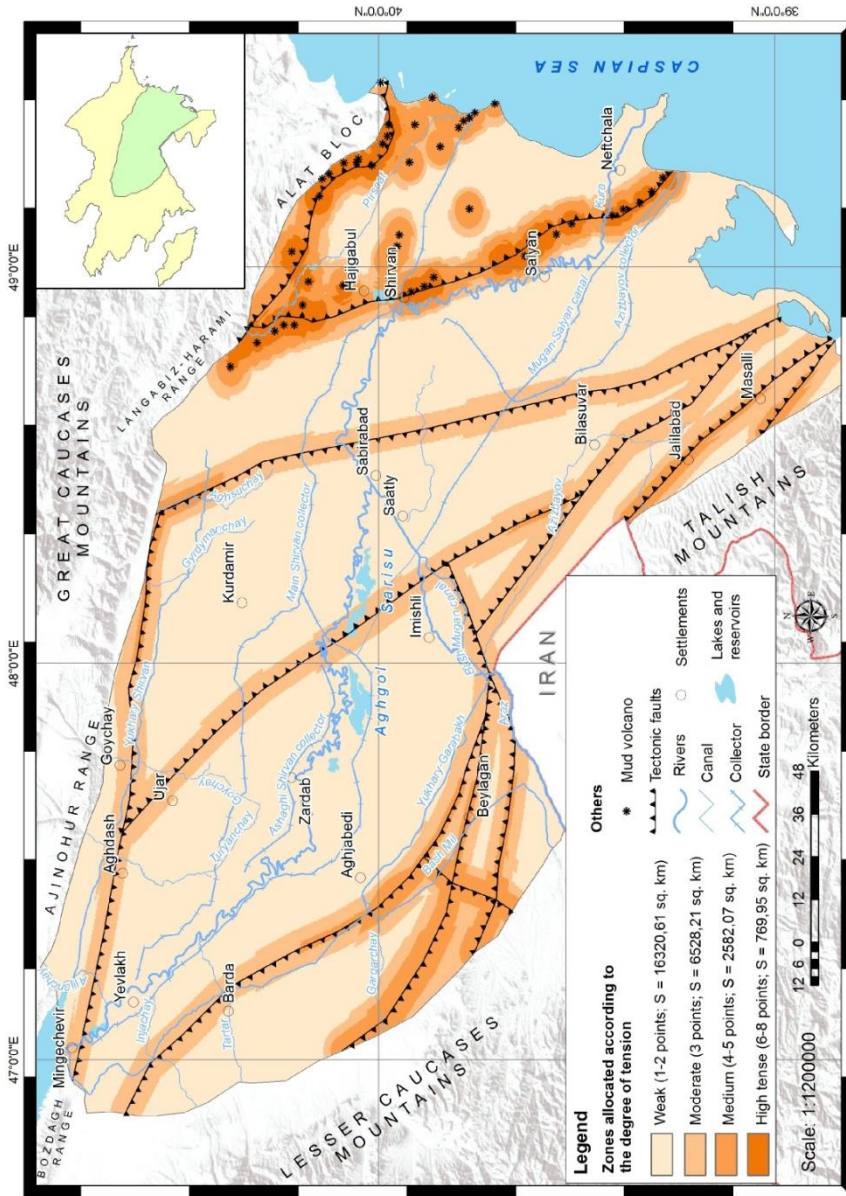


Figure 1. Ecogeomorphological zoning of the Kur-Araz lowland and surrounding areas due to endogenous factors

Medium tense zones (3–4 points; 5723.397 sq. km; 21.844%; 5 subzones) mainly cover Kurboyu, Shirvan, South-Eastern Shirvan and Salyan plains, Navahi depression, Hajiyolchu depression and surrounding areas. Intensive swamping, salinization, eolian and surface washing processes have developed in the mentioned areas. Intensive valley erosion is observed in the beds of the Shirvan rivers, complicated by bank shafts and ridges.

High tense zones (7–8 points; 3082.471 sq.km; 11.765%; 6 subzones) include intensive shield uplifts in the depressions, steep slopes, southeastern Shirvan and Salyan plains with developed sopka steppes, more exodynamically active banks of Kura and Araz rivers, and the shores of the Caspian Sea. Gully and gorge erosion, surface washing, and clay karst observed in the depression uplift have led to the formation of bedland-type areas. The intensive development of eolian processes in the vegetation-deprived areas, salinization processes in the low-lying areas of and mineralized groundwater of the South-Eastern Shirvan and Salyan plains, has created unfavorable ecogeomorphological conditions. Periodic floods and inundations on the banks of the Kura and Araz rivers, which are relatively densely populated, and periodic flooding and washing (abrasion) processes on the shores of the Caspian Sea have caused serious damage to settlements and arable lands at various times (Figure 2).

When conducting ecogeomorphological assessment of Kur-Araz lowland and surrounding areas on the basis of **morphometric indicators**, horizontal fragmentation caused by natural factors, hypsometry, vertical fragmentation and mean slope were taken as the main indicators.

The area of the weak tense (1–2 points) morphometric zone is 14869.446 sq. km, which is 56.75% of the total area. The weak tense zones cover the smooth (0-1 °) plains, where the erosion is weak and the accumulation processes are intensive, except the anticline uplifts. In a zone where surface washing processes are poorly developed and located at a hypsometric level below 0 m, the horizontal fragmentation varies from 0–0.4 km/sq. km, and the vertical fragmentation varies between 0 and 10 m.

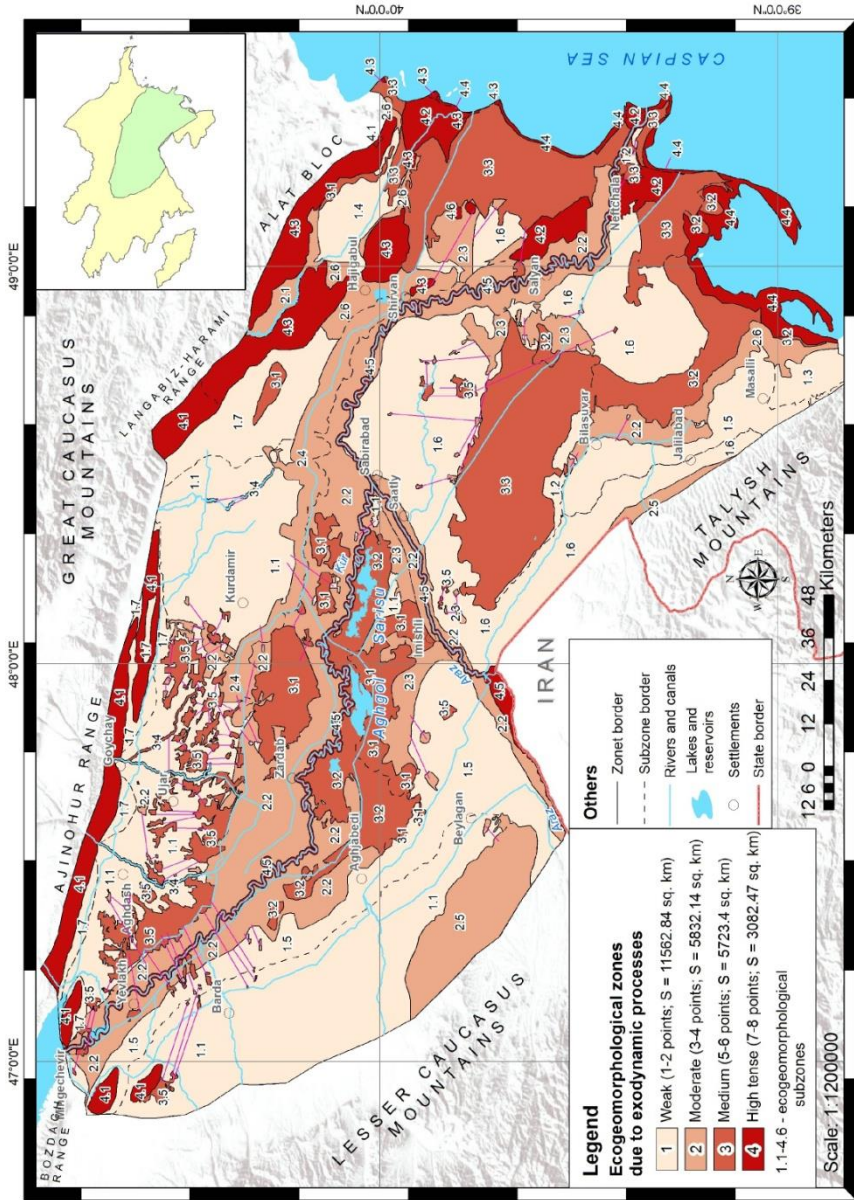


Figure 2. Ecogeomorphological zonation of the Kur-Araz lowland and surrounding areas due to exogenous factors

The area of the morphometric zone with moderate tension (3–4 points) is 8891.384 sq.km, which is 33.94% of the total area. In the formation of morphometric tension in the areas along the Kura and Araz rivers, in the Shirvan, South-Eastern Shirvan, Mugan, Mil, Garabagh plains, the horizontal fragmentation due to ravines and gorges, modern and ancient river valleys, former river-beds, and vertical fragmentation, caused by tectonic uplift in the foothill plains, plays an important role. Within the zone, the horizontal fragmentation varies from 0.4 to 0.8 km/sq. km, the vertical fragmentation varies from 10 to 100 m, the hypsometry varies from 0 to 100 m, and the mean slope varies from 1 to 2 °.

Morphometric zones medium (5–6 points) and high (7–8 points) tension cover inner depression uplifts of structural-denudation origin, mainly located in the northern and north-eastern parts. (Godakboz, Duzdag, Garamaryam, Padar, Garaja Bozdaghi, Khojashen-Goychay, Ingar, Langabiz-Harami, Mishovdagh, Alat anticline ridges and ridges), the western part of the sloping foothills of the Mil plain. The medium tense zone accounts for 7.74% (2027.564 sq.km) of the total area, while the high tense zone accounts for 1.58% (412.451 sq. km). Morphodynamic tension resulting from the interaction of endogenous and exogenous morphogenesis processes in the mentioned areas was manifested in the indicators of horizontal and vertical fragmentation and slope, which reached medium and high degrees. The Hajiyolchu salinity and surrounding areas are intensively fragmented by ancient and dry river valleys. Horizontal fragmentation within the medium tense morphometric region is 0.8–1.2 km/sq. km, vertical fragmentation and hypsometric value is 100–300 m, mean slope is between 2 and 10°, and within the high tense morphometric zone horizontal fragmentation is more than 1.2 km/sq. km, vertical fragmentation is 300–532 m, hypsometric value is 300–952 m and mean slope is 10–20.3 ° (Table).

The indicator of artificial fragmentation, which is found in most areas, was taken as the main **anthropogenic factor** influencing the ecogeomorphological conditions of the Kur-Araz lowland and surrounding areas (Figure 3).

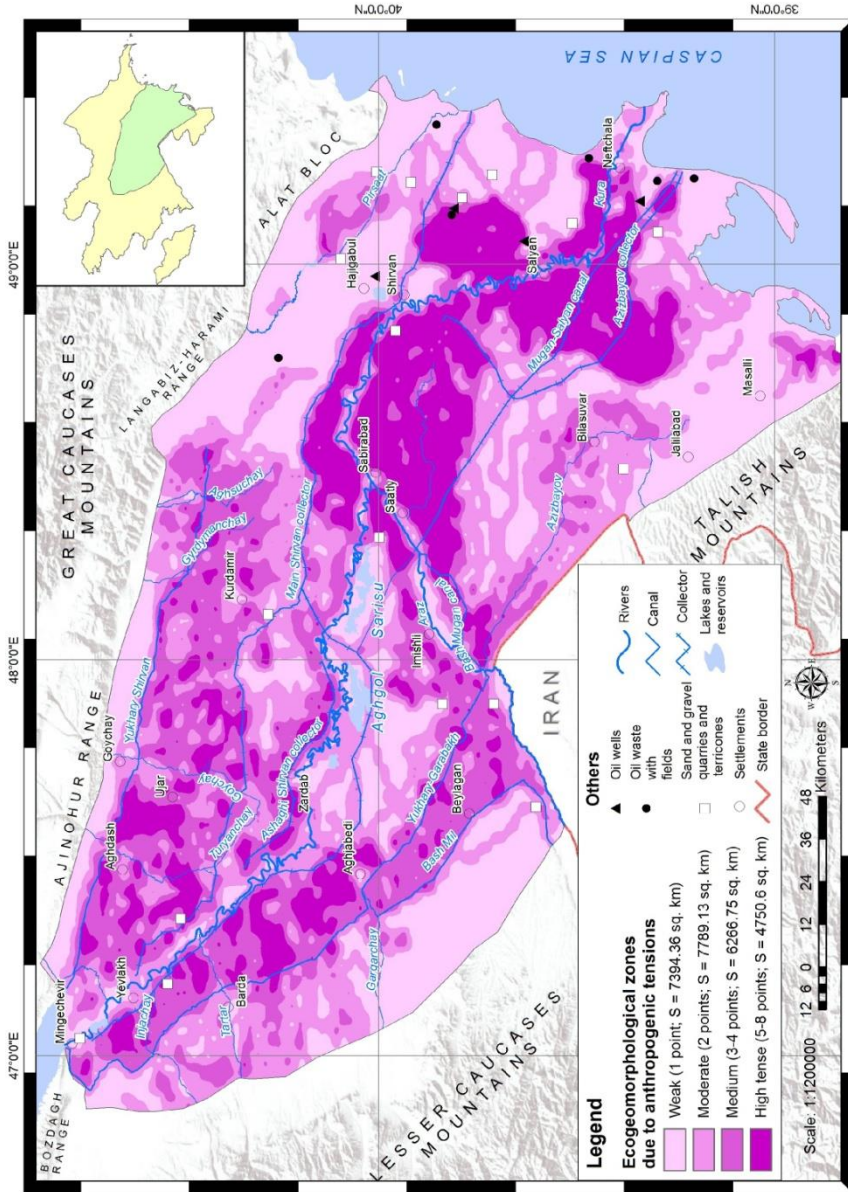


Figure 3. Ecogeomorphological zonation of the Kur-Araz lowland and surrounding areas due to anthropogenic factors

The ecogeomorphological zone with weak tension (1 point; 0–0.2 km/sq. km) accounted for 28.222% (7394.359 sq. km) of the total area. A weak tense zone covers poorly developed inner depression heights and blocs, which are unsuitable for agriculture, foothill Talysh and Mil plains, where surface washing and river erosion are developed, the South-Eastern Shirvan, Salyan plains, Hajiyolchu salinity, Sarisu lake-swamp system, where deflation and salinization and swamp processes are intensively developed, Caspian shore zone, where thalassogenic processes are observed.

Other territories of the Kur-Araz lowland and surrounding areas, were relatively suitable for agriculture and moderate (0.2–1 km/sq. km; 7789.135; 29.729%), medium (1–2 km/sq. km, 6266,749 sq. km; 23.918%) and high (more than 2 km/sq. km; 4750.603 sq. km; 18.131%) tense zones were separated depending on the density of anthropogenic fragmentation. Rising groundwater levels, caused by leakage of irrigation water from main, inter-farm and on-farm canals, in high tense zones with intensive irrigation erosion have led to the development of harmful exogenous processes such as re-salinization and swamping.

The main indicators of ecogeomorphological assessment of the Kur-Araz lowland and surrounding areas on the basis of **complex factors** are endogenous (mud volcanism, tectonic fractures, modern tectonic movements, seismicity), exogenous (exogenous morphogenesis processes), morphometric (horizontal and vertical fragmentation, hypsometry, slope) and anthropogenic (artificial fragmentation) factors were taken (Table).

The weak tense region (1–2 points; 8904.426 sq. km; 33.99%) covers the Shirvan plain, Navahi depression, Salyan, Talish foothills, Northern Mugan, Mil, Garabagh plains. Within the region, endogenous and exogenous factors were weak, morphometric factors were weak and moderate, and anthropogenic factors were moderate and high.

Moderate tense zone (3 points; 8172.666 sq. km, 31.19%) includes partly Shirvan, Salyan plains, foothills Navahi depression, central part of South-Eastern Shirvan plain, foothills Talish, North

Table

Ecogeomorphological zoning of the Kur-Araz lowland and surrounding areas according to complex factors

Ecogeomorphological zones	Endogenous factors, W*=17.4%			Exodynamic processes W*=37.6%	Morphometric indicators W*=32.7%				Anthropogenic factor km ² /km ² W*=12.3%	
	A*, km	B*, km	C*, mm/year		D*, points	E*, km ² /km ²	F*, m	G*, m		H*, °
Weak tense S*=8904.4. km ² (33.99%)	7 ≤	7 ≤	-5-0	≤7	Accumulation, weak erosion processes	0-0.4	0-10	-27-0	0-1	1.2 <
Moderate tense S*=8172.7 km ² (31,19%)	7	7	0-1	7	Accumulation, mild erosion processes	0.4-0.8	10-100	0-100	1-2	0.8-1.2
Medium tense S*=6077.8 km ² (23.2%)	6-5	6-5	1-2	8	Aeolian, salinization, swamping, erosion (field and valley) processes	0.8-1.2	100-300	100-300	2-10	0.4-0.8
High tense S*=3045.9 km ² (11.63%)	4-0	4-0	2 <	9	Intensive ravine erosion, salinization, eolian, washing processes	1.2-1.4 <	300-532	300-400 <	10-20.3	0-0.4

* In the table: W - specific weight; S - area; A - distance to mud volcanoes; B - distance to tectonic faults; C - modern tectonic movements; D - probable seismicity; E - natural horizontal fragmentation; F - vertical fragmentation; G - hypsometry; H - mean slope.

Mugan, Mil and Kurboyu plains, eastern parts of Garabagh plain. Within the zone, endogenous factors are weak, moderate and partially moderate, exogenous factors are weak, mild and moderate, morphometric factors are weak and moderate, and anthropogenic factors are partially weak and moderate, mainly moderate and high impact rates constitute compliance.

The medium tense zone (4 points; 6077.798 sq. km; 23.2%) partially covers the Shirvan plain, Sabaduzu and Navahi structural-denudation plains, South-Eastern Shirvan, Salyan, Kurboyu and foothill Mil plains. The region has weak, partially moderate and medium endogenous factors, partially moderate and high, mainly medium exogenous factors, mostly weak, partially moderate and medium morphometric factors, and mostly weak and moderate, partially medium and high levels of anthropogenic factors.

In the high tense zone (5–8 points; 3045.957 sq. km, 11.63%), the floodplain of the river beds (Kura, Araz rivers, etc.), the anticline series (Khojashen-Goychay, Ingar, Langabiz-Harami) and the ridges (Godekboz, Duzdag, Garamaryam, Padar, Garaja Bozdaghi, Mishovdagh, Alat), the shores of the Lesser Gizilaghaj Bay. The impact of endogenous and morphometric factors in the region is partially weak and moderate, mainly moderate and high, the impact of exogenous factors is partially moderate, mainly high, and the impact of anthropogenic factors is mainly weak and moderate, partially moderate and high.

CONCLUSIONS

1. According to the compiled morphometric maps, we determined that 68.43% of the area is located below 20 m (up to 3 points) and in more than 80% the value of slope and average slope (88.11%) is less than 2° (up to 4 points), in 76.63% of the area the value of vertical fragmentation is less than 20 m (up to 3 points). Such weak differentiation of hypsometric, vertical fragmentation and slope indicators is observed in most of the study area. Artificially increased horizontal fragmentation, which has a higher degree of fragmentation compared to the mentioned morphometric parameters,

plays a substantial role in the formation of ecogeomorphological tension, and in 57.21% of the total area its value is more than 1 km/sq. km (more than 5 points) [8].

2. A comparative analysis of natural and anthropogenic impacts on the ecogeomorphological conditions of the area was carried out on the example of horizontal (valley, gully-gorge network) and artificial (irrigation network) fragmentation. As the amount of fragmentation increased, the area of distribution of horizontal fragmentation decreased by the same gradations compared with anthropogenic fragmentation. The calculated maximum value of anthropogenic fragmentation in the study area (7.23 km/sq. km) was 2.5 times higher than that of the horizontal fragmentation (2.92 km/sq. km) [12].

3. Specific weights of individual factors were calculated during ecological-geomorphological assessment – according to endogenous factors: proximity to mud volcanoes – 46%, proximity to regional tectonic faults – 21%, modern tectonic movements – 22% and probable seismicity – 11%; according to morphometric indicators: horizontal fragmentation – 54%, vertical fragmentation – 28%, hypsometry – 13% and mean slope – 5%; according to complex factors: exogenous – 37.6%, morphometric – 32.7%, endogenous – 17.4% and anthropogenic – 12.3% [16].

4. Weak and moderate tense zones in the area, distinguished by endogenous, exogenous factors and morphometric indicators, are considered relatively suitable for most arable lands and settlements. These areas have undergone moderate and high anthropogenic fragmentation due to intensive development of agriculture (irrigated agriculture) [16].

5. It was determined that only in the north-eastern part of the study area overlap high-tense ecogeomorphological zones. New and modern tectonic movements accompanied by intense uplift, mud volcanism, tectonic faults, high seismicity, arid denudation processes have been intensively developed in the Langabiz, Kalamadin, Harami ranges and Mishovdagh, Alat ridges, and morphometric indicators

have a high value, and mentioned territories are characterized by high-tense ecogeomorphological conditions [16].

Proposals

1. Concreting of expired main and inter-farm canals and collectors, to regulate the level of groundwater in the area and prevent the development of re-salinization and swamping processes caused by them, the application of drip irrigation method, the expansion of closed horizontal collector-drainage network and vertical drains, phytomeliorative measures should be taken in areas with intensive development of erosion processes.

2. The establishment of innovative (solar, wind powered, etc.), modular desalination of water stations in areas where mineralized groundwater is close to the surface, as well as near the main drainage-collector systems, considering the lack of water in the area and construction of new desalination of seawater factories on the Caspian coast is required.

List of published scientific works on the dissertation:

1. Gasimov, J.Y. Ecogeomorphological conditions of Kura depression in the initial stage of neotectonic movements // Proceedings of the Geographical Society Azerbaijan, – Baku: Elm-tahsil, – 2012, – v. 17. – p. 155-160.

2. Gasimov, J.Y. Modern tectonic movements and their influence on ecogeomorphological conditions of Kur-Araz depression // Materials of the scientific-practical conference "Heydar Aliyev and the development of geography in Azerbaijan" dedicated to the 90th anniversary of national leader Heydar Aliyev, – Baku: – 2013, – p. 321-324.

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5. Gasimov, J.Y. Analyses of endodynamic processes influencing on ecogeomorphological conditions of Kura depression (on example of Kura-Araz plain) // Geographical problems of the regions of Azerbaijan, Materials of the Republican scientific-practical conference, - Baku: Baku University Publishing House, - 2016, - p. 210-215.

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16. Gasimov, J.Y. Ecogeomorphological zoning of the Kura-Araz lowland and adjacent territories based on complex factors // The XXV International Scientific Symposium. Civilizational bridges between people and cultures, – Kiev: Caucases Education Publications, – 2022, – p. 187-190.

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